Fuel Choice for FCVs: Hydrogen Infrastructure Costs

Stephen Lasher

15 Acorn Park
Cambridge,
Massachusetts
02140-2390
lasher.stephen@tiax.biz

DOE Hydrogen, Fuel Cells and Infrastructure Technologies Annual Review Presentation

Philadelphia Marriot
Philadelphia, Pennsylvania
May 24-27, 2004

This presentation does not contain any proprietary or confidential information

Objectives

Evaluate the costs of a hydrogen (H_2) transition and identify pathways to minimize stakeholder risks.

- Analyze transition scenarios that are associated with developing a hydrogen infrastructure for FCVs
  - Determine investment risk and economic viability
  - Consider additional important fuel chain/vehicle combinations as appropriate
- Identify key economic barriers and possible development paths
  - Assess impact on various stakeholders and how risks could be shared and minimized
  - Evaluate scenarios that could bring down the initial costs of hydrogen (added scope)

Budget

- Total funding for the project = $532,000
  - DOE = $415,000
  - TIAX = $117,000
- FY04 funding = $80,000 (DOE)
  - This project also supported TIAX's role in the H2A working group[1]
  - Although H2A-related activities were a significant effort this reporting period, that work will not be presented here

[1] The H2A effort was organized to develop the building blocks and frameworks needed to conduct rigorous analysis of a wide range of hydrogen technologies. In February 2003, a group of analysts who are focused on addressing economic, energy and environmental aspects of hydrogen (the "H2A Working Group") came together for the first time to discuss potential merits and objectives that working group might bring to the HFCIT Program. Analysts from national laboratories, research organizations, and contractors have participated in the group.

Barriers/Targets

This project addresses the following technical barriers from the HFCIT Program Multi-Year R,D&D Plan:

- Production
  - AD. Market and Delivery
- Delivery
  - A. Lack of Hydrogen/Carrier and Infrastructure Options Analysis
- Storage
  - V. Life Cycle and Efficiency Analysis

The project also supports the HFCIT Program target setting.

We modified last year's NPV model based on stakeholder input and evaluated transition scenarios.

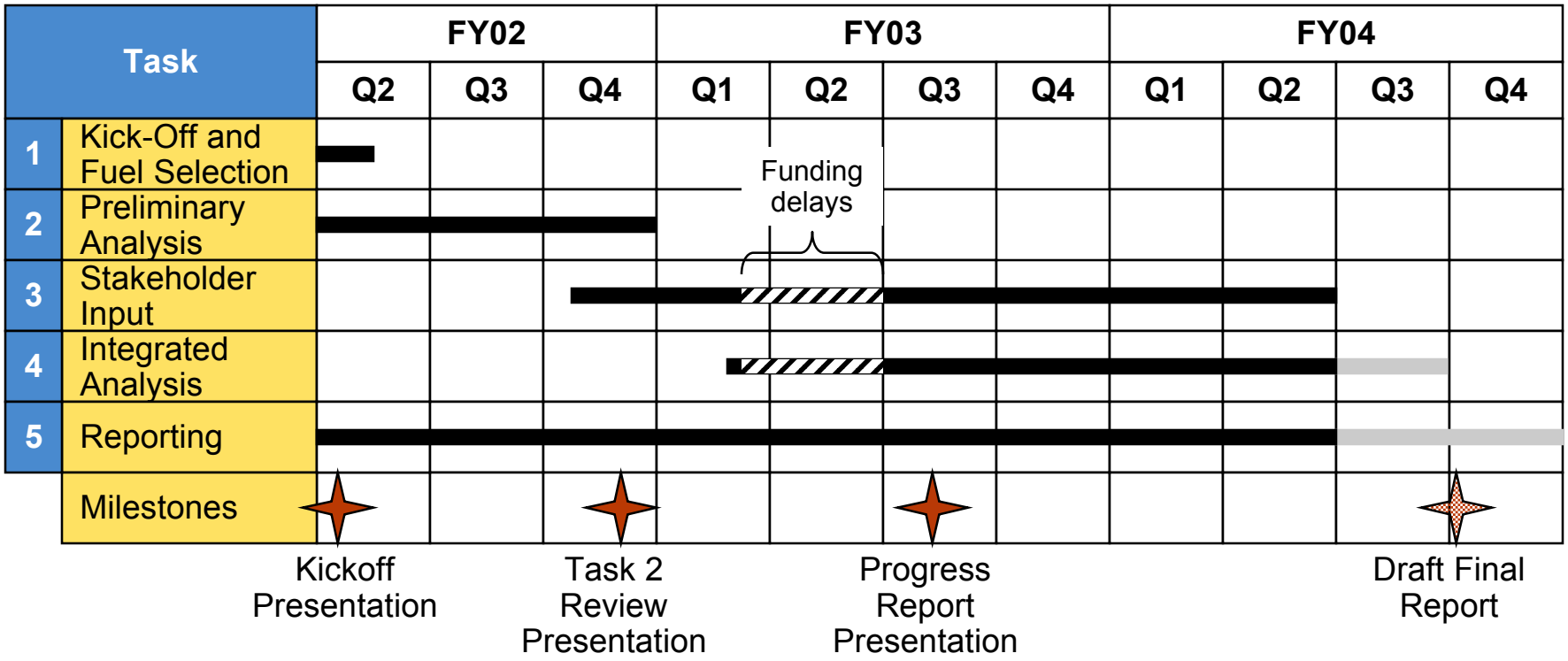
- Obtain stakeholder feedback on preliminary assumptions and "strawman" results and modify NPV model accordingly
  - Incorporate regional-based transition scenarios
  - Consider impacts of mobile fuelers and hydrogen ICEVs
- Calculate capital costs and NPV results for various transition scenarios using the model
  - Compare results for investment, cash flow, and NPV to identify key barriers, possible development paths, and risks to various stakeholders
  - Incorporate scenarios that could bring down the initial costs of hydrogen (added scope)

Safety

- There are no safety aspects per se do to the analytical nature of the work

Timeline

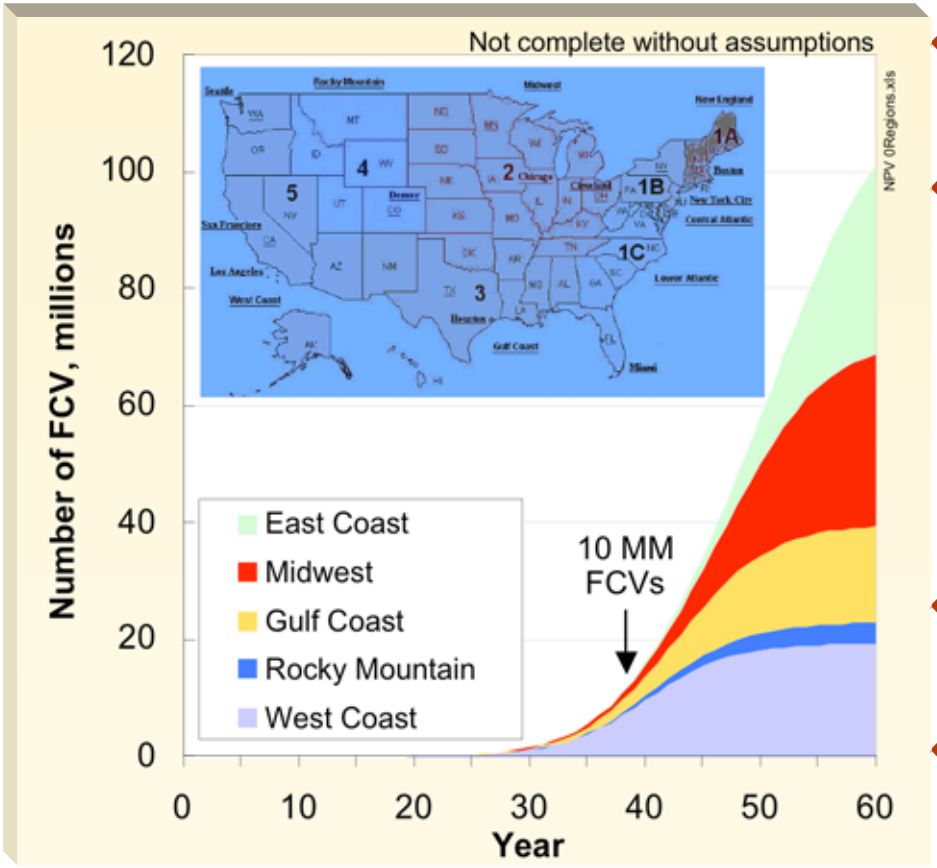
The timeline has been extended due to additional scope to evaluate low-cost hydrogen pathways (added to Task 4).



Note: The recent milestones related to the H2A work have not been included.

Based on stakeholder input, the NPV model has been modified for distinct regional introduction of H_2 vehicles.

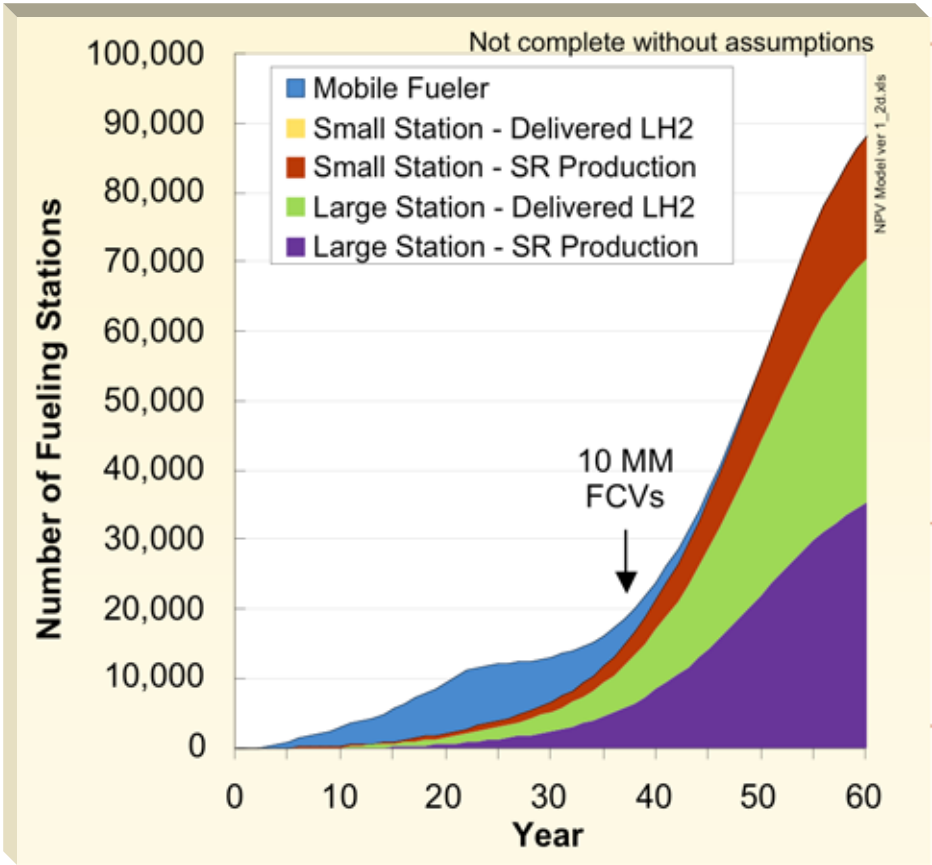
Example: Regional H_2 FCV Introduction based on DOE Vision Model Conservative Scenario



- PADD regions were used to segregate the country
- Vehicle introduction is assumed to start in one region and move gradually to others
  - Allows for meeting regional fueling station coverage with reduced economic risk versus achieving immediate national coverage
- Any vehicle introduction scenario can be evaluated with the model
- An option to incorporate the introduction of H_2 ICEVs has been added (not included in this example)

The model can now more accurately evaluate various infrastructure build-up approaches.

Example: Regional H_2 Station Build-up with Mobile Fuelers – National Total

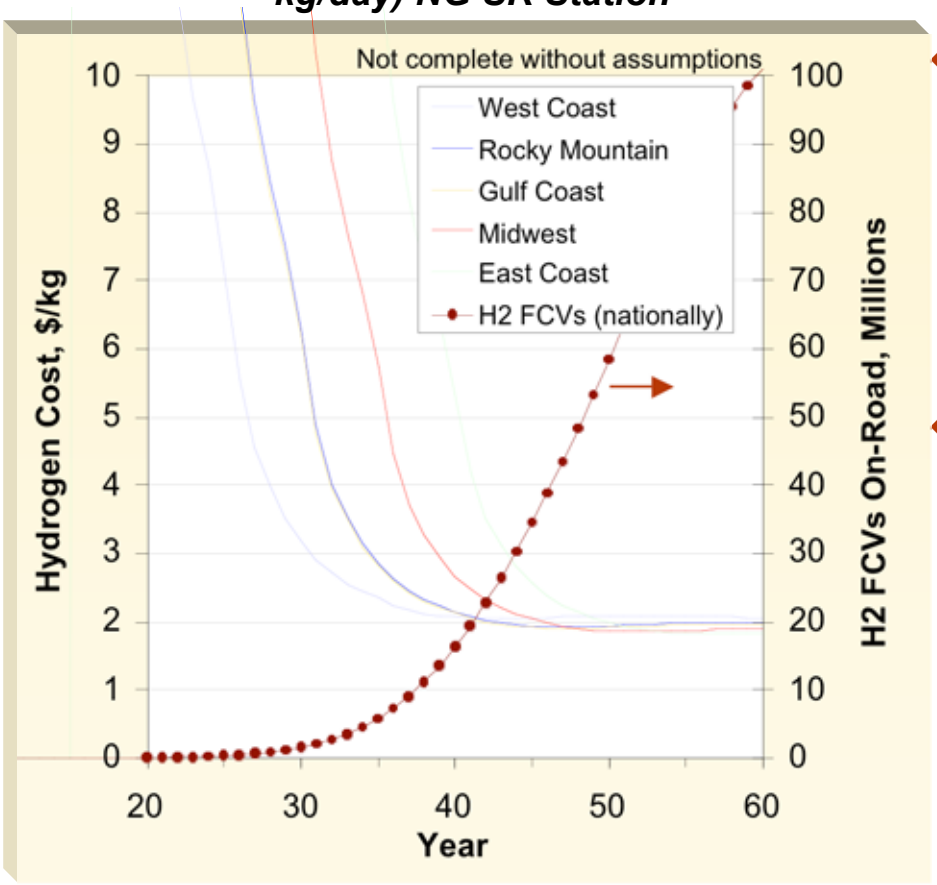


- H_2 fueling stations are introduced regionally to meet assumed H_2 demand and station coverage[1]
  - No longer use simple capacity factor input assumptions
  - Assumptions can be made about urban versus rural station coverage and market shares over time
- Large and small capacities were changed to 1500 and 100 kg/day, respectively (consistent with H2A)
- An option to include mobile fuelers has been added

[1] Coverage refers to the number of fueling stations with hydrogen capacity divided by the total number of fueling stations.

The NPV model can be used to evaluate the cost of hydrogen from various pathways in each region over time.

Example: Regional H_2 Costs – Large (1500 kg/day) NG SR Station

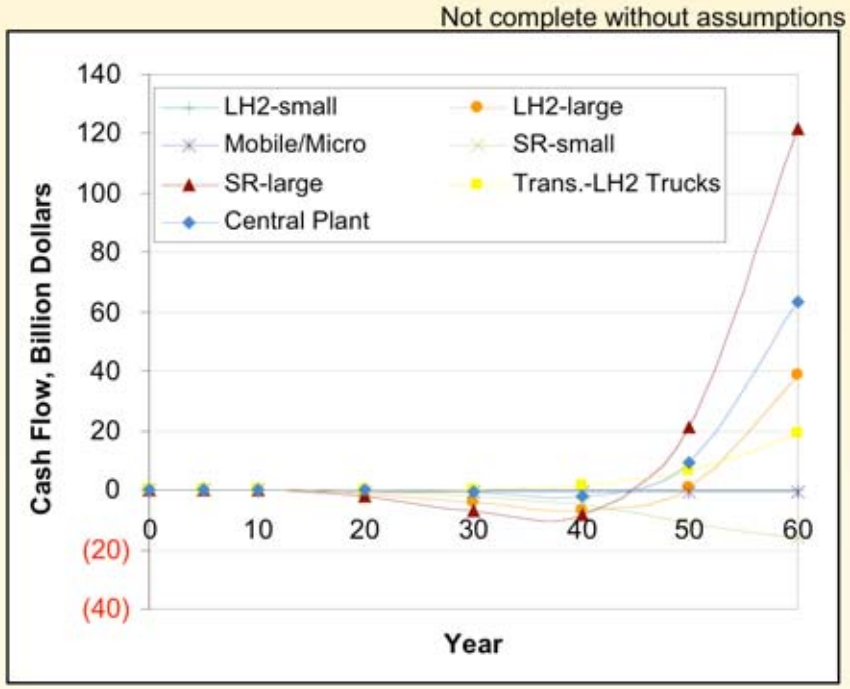


- In all regions, H_2 production costs would ultimately reach $2/kg but initial costs are high
  - Early H_2 capacity/sales will likely require subsidies to be competitive with gasoline
- H_2 costs depend strongly on station capacity factors
  - H_2 costs are high for later regions despite assumed reduced capital costs due to "economies of scale"

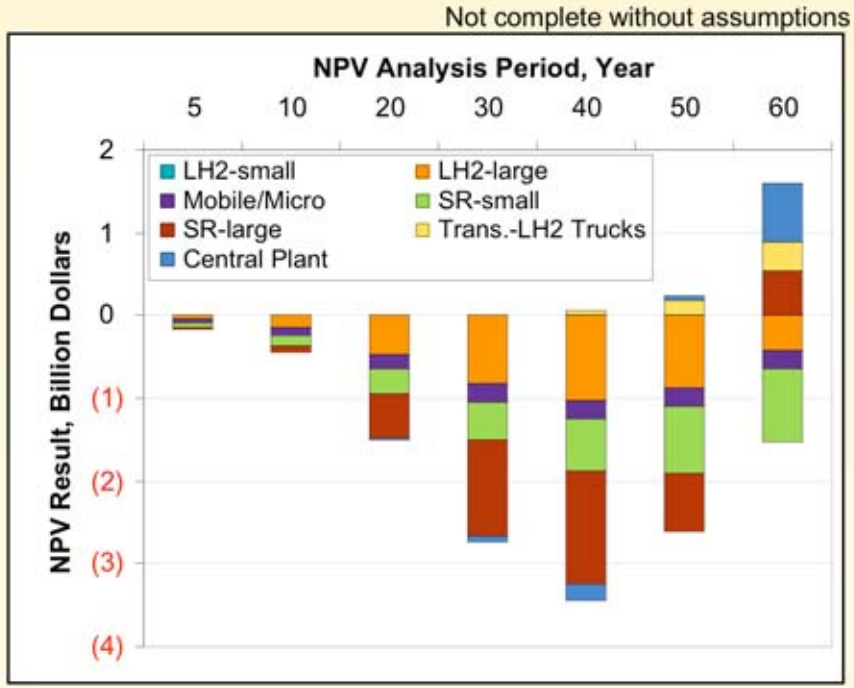
[1] Economies of scale: intensively using expensive machinery, buying supplies in bulk for a discount, developing new and better products, etc.

We can use the analysis to evaluate stakeholder risks and the economic viability of various pathways.

Example: Cumulative Cash Flow



Example: Net Present Value

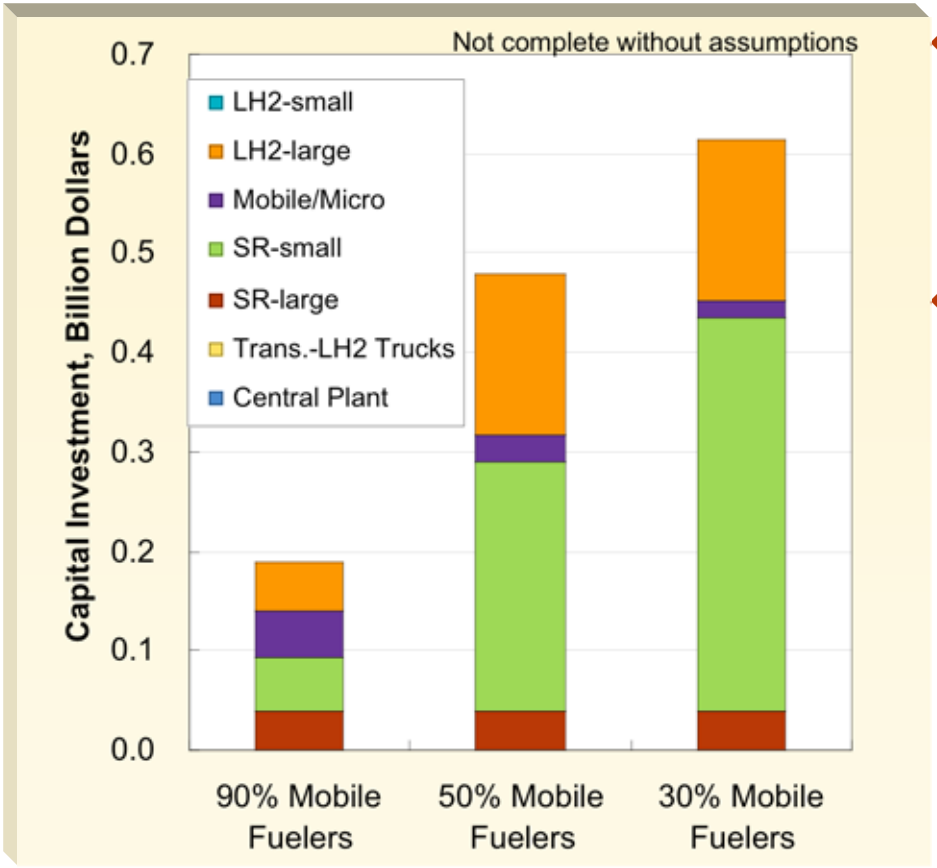


Note: Results assume a range of hydrogen selling price over time as a function of gasoline price, road tax assumptions, and vehicle fuel economies.

In these examples, it is a very long time before any stakeholders are able to turn a profit and even longer before they recover their investments.

Scenarios have been developed to determine the least cost or lowest risk approaches.

Example: Mobile Fuelers Impact – Capital Investment through 2013 in CA only



- We can evaluate various infrastructure build-up approaches
  - Mix of fueling station types to meet regional coverage and H_2 demand
- In this example, mobile fuelers significantly reduce the initial capital investment required
  - Existing LH_2 capacity in CA can meet the 2013 demand from vehicles
  - If new central plant capacity is required, mobile fuelers are not as attractive

Note: In this example CA has sufficient LH_2 capacity to meet demands for hydrogen up to 2013. Therefore, no new central plants need to be installed.

The examples used here were generated to demonstrate methodology and validate the analysis approach...

- We are in the process of evaluating lower-cost pathways:
  - Utilizing existing excess hydrogen capacity to reduce early capital investments
  - Considering the effects of FCV demos and fleets, hydrogen ICEVs, and energy stations to improve capacity factors
- There is significant on-going work at DOE and in various industries to bring costs below those projected here
  - We did not use DOE targets
  - Using assumptions consistent with DOE target of $1.50/kg would result in a much brighter outlook

…significant additional work will be conducted to generate additional scenarios in the final analysis.

We have met with stakeholders and others outside of DOE to present our results/perspectives and solicit feedback on our progress.

Event (since last Merit Review period)	Stake-holder	Other
Exxon-Mobile Presentation and Review, Fairfax VA	●	
SAE Powertrain & Fluid Systems Conference, Pittsburgh PA		●
Fuel Cell Seminar, Miami Beach FL		●
Shell Presentation	●	
International Conference on Fuel Cell Development and Deployment, Storrs CT		●
Council for Chemical Research 25th Annual Meeting, Tampa FL		●
National Hydrogen Association Meeting, Los Angeles CA		●

Reviewer Comments

- Underlying assumptions need to be stated clearly
  - Response: Detailed assumptions will be presented in the final report. Unfortunately there are a large number of important assumptions and very little space to present them here.
- Fueling station coverage is out of line with even the lowest penetration estimates by DOE and even more out of line with less optimistic estimates
  - Response: Recent announcements by energy companies indicate that they now believe 12,000 fueling stations **nationally** may be sufficient for early coverage. These latest announcements appear to be in line with our results. However we will continue to obtain industry feedback on this and other assumptions/results.
- Study lacks system and socioeconomic perspective particularly in use and market penetration
  - Response: The model inputs are based on detailed system integration in terms of hydrogen production, delivery, and dispensing that cannot be accurately represented in this limited space.
  - The socioeconomic perspective in terms of energy and environmental impacts will be incorporated into the final report.
  - Original analysis of hydrogen vehicle market penetration is outside the scope of this work. However, any vehicle introduction scenario can be evaluated with the model.

Future Work

For the final report, we will develop additional transition scenarios and compare their impacts on stakeholders.

- Validate and modify inputs if necessary based on H2A
  - As part of the H2A, TIAX is developing industry vetted assumptions and results for long-term H_2 costs (excluding transition issues)
- Identify key economic barriers and possible development paths (continued)
  - Evaluate additional scenarios that could bring down the initial costs of hydrogen
  - Evaluate potential impacts on the existing infrastructure
  - Determine what may trigger the introduction of hydrogen fueled FCVs (e.g. oil price increase, carbon taxes, FCV cost reduction)
- Determine energy and environmental impacts of scenarios
- Arrive at a joint DOE/industry understanding of the situation and complete draft and final reports